Title: Digital interventions for screening and treating common mental disorders or common mental illness symptoms in adults: A systematic review and meta-analysis

Short and running title: Online interventions for common mental illness symptoms

Abstract

Background: Digital interventions targeting common mental disorders (CMD) or CMD symptoms are fast-growing and gaining popularity, probably in response to the increased prevalence of CMD and better awareness of early help-seeking and self-care. However, no previous systematic reviews focusing on these novel interventions were found.

Objectives: This systematic review aimed to scope entirely web-based interventions which provided screening and signposting for treatment, including self-management strategies, for people with CMD or sub-threshold symptoms. In addition, a meta-analysis was conducted to evaluate the effectiveness of these interventions for mental wellbeing and mental health outcomes.

Methods: Electronic databases (MEDLINE, PsycINFO, CINAHL, EMBASE, CENTRAL, Web of Science, ASSIA, DARE, HTA, and NHS EED) were searched from 1st January 1999 to early April 2020. We included randomised controlled trials (RCT) which evaluated a digital intervention (1) targeting adults with common mental health disorder symptoms, (2) providing both screening and signposting to other resources including self-care, and (3) delivered entirely through the internet. Intervention characteristics including target population, platform used, key design features, and outcome measure results were extracted and compared. Trial outcome results were included in a meta-analysis on the effectiveness on users' wellbeing and mental health outcomes. Health economic data were used to compile cost-effectiveness analysis. We also rated the meta-analysis results with GRADE to establish the quality of the evidence.

Results: The electronic searches yielded 21 papers describing 16 discrete digital interventions. These interventions were investigated by 19 unique trials including one health economic study. Most studies were conducted in Australia and North America. Populations targeted varied from the general population to allied health professionals. All interventions offered algorithm-driven screening with measures to assess symptom levels and to assign treatment options including automatic online psychoeducation, self-care strategies, and signposting to existing services. Meta-analysis of usable trial data showed that digital interventions improve wellbeing (3 RCTs, n = 1307, SMD 0.40, 95% CI 0.29 to 0.51, I^2 = 28%, fixed effect), mental illness symptoms (6 RCTs, n = 992, SMD -0.29, 95% CI -0.49 to -0.09, I^2 = 51%, random effects) and work and social functioning (3 RCTs, n = 795, SMD -0.16, 95% CI -0.30 to -0.02, I^2 = 0%, fixed effect) comparing to waitlist or attention-control. However, scarce follow-up data failed to show any sustained effects beyond the post-intervention timepoint. Data on mechanisms of change and cost-effectiveness was also lacking, precluding further analysis.

Conclusions Digital mental health interventions to assess and signpost people experiencing CMD symptoms appear to be acceptable to sufficient number of people and to have enough evidence for effectiveness to warrant further study. We recommend future studies incorporate economic analysis and process evaluation to assess mechanism of actions and cost-effectiveness so to aid scaling up implementation.

Keywords: Digital health; mental wellbeing; common mental illness; depression; anxiety; self-care

Background

There are several reasons to study standalone digital technology interventions as the first step in assessment and management of symptoms of common mental disorder (CMD). CMDs include different types of depression and anxiety and can cause marked emotional distress and interfere with daily function [1,2]. First, access to digital technologies is high in many countries and increasing in many others [1,2]. Second, mild disorders frequently remit without professional treatment and instead self-management strategies can be learned to ameliorate symptoms and prevent future episodes [3]. Third, there are many digital interventions available for common mental disorders and related problems such as poor sleep [4], and for the promotion of mental wellbeing such as mindfulness [5]. Some have been subjected to rigorous evaluation [6], while others have not been per se but are digital applications of evidence-based therapies such as cognitive behavioural therapy (CBT). Fourth, there is evidence that common mental disorders are increasing in prevalence in groups such as young women and people aged 55-64 [7], and it is not possible to meet these needs in primary care or specialist mental health service based on current resources and workforce supply [8,9]. Fifth, it should not be assumed that digital interventions are a cost-effective way to meet needs that cannot currently be met by the health workforce. They carry development and maintenance costs and the work entailed must ensure usability and acceptability. Further, for costs to be offset the intervention must be accessed by sufficient numbers of people who experience benefit above and beyond any other service they may be accessing; ensuring this widespread awareness among people likely to benefit also carries costs [10]. Sixth and last, many people prefer to manage their symptoms without recourse to professional services, often due to a desire for self-reliance, but also for reasons such as fear of stigma and discrimination, and barriers in accessing specialist mental health treatment, for example due to working hours, need of a GP or medical referral, or rural location [11,12].

Our starting point for this review is the development and launch in 2017 of one such digital intervention, *Good Thinking*, for people living and working in London, UK (www.good-thinking.uk). Good Thinking provides initial assessment and signposting to online self-guided interventions, including self-care and community-based resources, virtual or otherwise, entirely online. This comprises four modules, on sleep problems, stress, low mood and anxiety, and includes a self-assessment and signposting to mental health self-management apps, digital therapies (e.g. Sleepio for sleep problems [13] or FearFighter – an online CBT for social phobia or panic disorder [14]) and conventional services. The apps were approved by *NHS Digital*, the organization in charge of digital services within the UK's National Health Service (NHS), using a pre-existing quality control process which includes consideration of the evidence base applied in the digital treatment [15]. The user can choose one of these four modules and be signposted based on responses to questions on the online platform, which can be answered regarding the self or someone they know. Alternatively, the user can use a self-assessment for tailored signposting based on algorithms used for the national telephone helpline, NHS 111.

Good Thinking thus differs to digital therapy delivery which has been the subject of previous reviews [16-21]. These reviews, although focusing on CMD (such as depression and anxiety disorders [6,18], post-traumatic stress disorder [17,22], and insomnia [16]) investigated effectiveness of digital psychotherapies, mostly on CBT provided by healthcare professionals albeit with varying degrees of synchronised or asychronised guidance delivered online. Such interventions tend to follow an assessment conducted by a health professional to validate diagnosis and include further therapist-delivered psychological interventions, using various media. Instead, Good Thinking exemplifies a new breed of digital mental health interventions which allow users to be in complete control of the

process, from access, to assessment, intervention emphasizing self-management, and outcome assessments. These users may have CMD symptoms not necessarily meeting diagnostic or mental health service thresholds, or not needing specialist services or conventional therapist-led interventions. Many are primarily interested in seeking out digital applications that promote self-care for wellbeing, signposting to alternative services such as a helpline, and peer support forum. As such, this broad range of interventions are likely to be sought by a wide population at a time when many countries are promoting awareness and self-care for mental health, such as Every Mind Matters in England (www.nhs.uk/oneyou/every-mind-matters/) and BeyondBlue in Australia (www.beyondblue.org.au/).

To the best of our knowledge, no previous reviews have been undertaken focusing on the potentially heterogeneous populations using interventions which like Good Thinking include a self-assessment in order to help an online user choose their next step in terms of self-management or help-seeking. This review of the interventions and their evaluation will contribute to the development and implementation of more successful applications and, hence more effective and sustainable web-based interventions.

Objectives

Our aim was therefore to conduct a comprehensive systematic review of studies of digital mental health services that provide online self-assessment and treatment emphasising self-care for people with common mental health disorders or sub-threshold symptoms. We examined randomised controlled trials (RCT), the fairest and most robust study design in evaluating the effectiveness of entirely web-based interventions that aimed to optimise mental health related outcomes and intermediate outcomes including uptake of self-care, informal support or treatment services. We planned to conduct meta-analyses on the (cost-) effectiveness of the interventions on mental wellbeing and CMD symptom outcomes. Using the research evidence, we also aimed to examine the evidence for mechanisms of actions of such interventions, through intermediate or health behavioural change outcomes to mental health outcomes.

Methods

Data sources and search strategy

Searches for papers written in English, from 1st January 1999 (when e-/digital health interventions were first documented) to 20th September 2018, were conducted using: MEDLINE and MEDLINE in-process; PsycINFO; CINAHL; EMBASE; Cochrane Central Register of Controlled Trials (CENTRAL); Web of Science; ASSIA; Database of Abstracts of Reviews of Effect (DARE); HTA published and in-process; and NHS EED. Once an initial set of included papers from the databases were identified, we performed backward and forward searches in their reference lists and citations of identified papers for any additional studies. We also contacted authors of included papers to retrieve relevant information about their study when unclear from the published article. To identify articles not included in our original search, we tracked published protocols of trials identified in 2018 and conducted an update search on MEDLINE, PsycINFO, EMBASE, ASSIA and WoS for any new publications up to 9 April 2020.

We devised the search terms using the PICO approach [23]. As the search aimed to be highly sensitive, we employed an initial search strategy combining search terms for population (e.g.

common mental health disorders, adults, depression, anxiety) and interventions (e.g. digital/ehealth*/mhealth*/web/online/internet adj3 intervention/program*/initiative*/group*). We refined and adapted the search terms used suiting the different database search systems. We have published the review protocol in PROSPERO (CRD42017079085) [24]. The review process followed PRISMA guideline [25].

Study eligibility and selection

We included studies targeting adults aged 18 or above, with no upper age limit. According to the UK Adult Psychiatric Morbidity Survey (APMS [7]), CMDs include different types of depression and anxiety and can cause marked emotional distress and interfere with daily function, but do not usually affect insight or cognition. CMD symptoms include somatic symptoms, fatigue, sleep problems, irritability, worry about physical health, concentration and forgetfulness, depression, generalised worry, anxiety, phobias, panic, compulsions, and obsessions [7]. We also consulted experts in the field to establish if certain illness types or symptoms, not covered by the APMS definitions, fit the criteria of CMD. Examples included perinatal depression.

We included studies of any digital mental health interventions which aimed to support individuals directly and delivered using web-based information and communication technology (ICT) entirely. Facilitation by non-digital resources, such as professionals or lay persons, did not affect study inclusion as far as the intervention was delivered using internet ICT completely. We specified that intervention contents must cover: screening or (diagnostic) assessment; and with self-care for mental health promotion or symptom management as part of the treatment which can also include information-giving, signposting or recommendations, informal support, and pre-existing treatment options. We excluded interventions designed to provide solely assessment or treatment, but not both. In order to examine the (cost-) effectiveness of identified interventions, we included only empirical studies using an online RCT design for optimal external and internal validity [26] and with intervention-recipients/users' outcomes reported using validated quantitative measures.

One author (AT, JC, EM, or JS) screened all retrieved items through their titles, abstracts, and then full text. Another author (JS or GG) conducted an independent check on a random 20% sample of all items at each step, with a third author (CH) reviewed a proportion of searches, screening and study selection. Disagreements were resolved through: (1) seeking additional data or clarification from study authors when possible; and (2) review team discussion. All study selection process was conducted using EndNote software v8.0 (Clarivate Analytics).

Outcomes and measures

For this comprehensive review, we set a range of primary outcomes focusing on participants' CMD symptoms and related domains. These included: mental illness symptoms; wellbeing; quality of life; perceived social support; work and social functioning; self-efficacy or coping; and adverse events. Process and/or intermediate outcomes were specified as health behaviour change or proxy measures which are conduit to primary outcomes. These included uptake of recommendations on self-care strategies and increased behavioural activation (such as goal setting, self-monitoring, general communication skills) [26]. In addition, we examined data on satisfaction or perceived acceptability of intervention.

Data extraction and analysis

Relevant extracted data were entered into the included studies summary table devised by the review team. We extracted study design and data variables from each included study for further analysis, including: sample size; setting; participant characteristics (such as age, gender, diagnosis or symptoms or complaints, and ethnicity); outcome measures; time-points; and control condition or comparator. Data on the intervention extracted were as follows: aim(s); theoretical framework if used and described; content and features; duration of intervention both in terms of usage hours if specified and the period during which the intervention was undertaken.

Regarding the theoretical framework, we scoped the theoretical basis used by the studies (e.g. social cognitive theory, health belief model), the use of theory (e.g. theory/predictors used to select recipients for the intervention) in informing intervention design [27] and any behaviour change techniques employed by the identified intervention (e.g. stress management, goal setting) [28]. We devised a coding system for these factors as they have been established to be particularly effective in promoting intervention uptake and effectiveness [28-30].

Data extracted on content and features included:

- the modes of delivery, access and overall approach of the interventions;
- Online (i.e. eHealth), or mobile (i.e. mHealth), or both e- and m-health;
- With social networking function, or no social network, or combined therapy and social networking;
- Free vs paid vs depending on contract;
- Treatment options including self-care/management, informal support (such as using peer support or community support resource) or signposting to formal or statutory services.

Data analysis started with an overview of study and intervention characteristics followed by tabulation of extracted data. All data deemed relevant for each review objective were grouped together and synthesised using a narrative approach. When sufficient homogeneous data were available, we conducted meta-analyses to investigate effectiveness of treatment, using Review manager (version 5.3, The Cochrane Collaboration, Copenhagen, Denmark). Meta-regression to investigate the significance of identified moderators on treatment effectiveness was to be considered in the event of 10 or more studies were included in a meta-analysis [31]. We used a fixed-effect model when there were <5 studies included in the meta-analysis and random-effects model when there were 5 or more studies [31]. In addition to conducting overall analyses comparing digital interventions with all comparators pooled together, we also conducted separate comparisons of digital interventions against all inactive controls (e.g. wait list or usual care); and digital interventions against active controls (e.g. interventions augmented with a non-digital element such as therapist support via face-to-face or phone contact or attention controls). As the outcomes were measured with different validated scales, we calculated standardised mean difference (SMD) and 95% confidence interval (CI) for continuous outcomes; and risk ratio (RR) and its 95% CI for dichotomous data [32]. Statistical heterogeneity was quantified using the I-squared (I^2) statistics in addition to the visual inspection of the forest plots; with I^2 values above 50% interpreted as evidence of substantial levels of heterogeneity [31]. Although some consider SMDs of 0.2, 0.5, and 0.8 as small, medium, and large effects, the magnitude of these effects alone have been criticised as not bearing any relationship with their clinical importance [31]. Instead, the SMDs should be interpreted within the context of overall quantity and quality of the data included in the meta-analysis (see below).

Assessment of study and evidence quality

We used the integrated criteria for review of multiple study designs (ICROMS [33]) to assess included study quality. All studies were assessed for seven dimensions: clear aims and justification; managing bias in sampling or between groups, in follow-up, and in other study aspects; analytical rigour; and managing bias in reporting/ethical considerations. Each criterion was evaluated on a three-point scale (2 = criterion met; 1 = unclear; 0 = criterion not met). The ICROMS minimum score requirement for RCTs, including cluster (i.e. 22) was used to rate the trial quality rather than to exclude studies on grounds of quality, to retain usable data [33]. In addition, we also used the CONSORT eHealth Checklist (v.1.6.1) [34] to assess the trial reporting quality. For health economic studies, we used the Consolidated Health Economic Evaluation Reporting Standards (CHEERS Checklist [35]) to assess specialty study quality. Quality assessment was conducted by two authors (EM, GG, or JS) independently and health economic studies assessed by an expert in the field (BB). In the event of discrepant assessment results, we resolved them for consensus through: (1) seeking additional data or clarification from study authors when possible; and (2) review team discussion.

For collective data pooled into meta-analyses, we assessed the quality of the evidence for each analysis using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [31,36]. One of four levels – high, moderate, low, or very low – were assigned to the overall quality of evidence for each outcome, according to factors including within-study risk of bias (methodological quality), directness of evidence, heterogeneity, precision of effect estimates and risk of publication bias.

Results

The search initially retrieved 25,586 records. A stepwise process of screening titles, abstracts and full-text papers against our eligibility criteria was used to identify 417 full-text articles for the final screening stage. Of these, 21 papers covering 19 discrete study data sets were included [5,37-54]. One RCT paper [55] included partial data from an earlier paper investigating the same tailored e-health intervention with the same sample in the Netherlands [41], hence we only used data extracted from the latter which also reported trial registration details. Similarly, we included the main paper out of two that reported on the same trial of a digital public mental health programme in Hong Kong [43,56]. The search process results are shown in Figure 1, and the summary of included studies is shown in Table 1.

INSERT FIGURE 1 and TABLE 1 HERE

Overview of included studies

Overall, the included studies covered 6223 participants in intervention conditions and 5797 in comparison conditions. Most of the studies (n=8 including a cost-effectiveness study) [37-39,44-46,49,52] were conducted in Australia. Four were conducted in the U.S.A [5,40,42,48]. The remaining studies took place in Europe, including Lithuania [50,51], the UK [54], the Netherlands [41], Germany [47], and Norway [53]. Lastly, one study originated from Hong Kong, China [43].

Studies recruited adults with subclinical or mild CMD symptoms among the general population in the community, many through social media (Facebook and Twitter) advertisements [5,37,38]. Nearly half

of the studies aimed at promoting positive wellbeing and targeted users with some indication of clinical symptoms, including university students [42,44-46,48,49] and the general public who were interested in self-care to promote wellbeing [5,38,39,43,47,54]. The remainder targeted populations with increased risk of mental health morbidities either due to work-related stress or health conditions. These included nurses and allied health professionals [41], technology company employees [40], and pregnant or post-partum women and their partners for preventing or managing post-partum depression [53]. Very few studies targeted populations with above clinical threshold CMD symptoms. The exceptions included studies trialling an e-mental health treatment for those with mild to moderate depression [37] or marked adjustment disorder symptoms [50,51].

Across included studies, female participants comprised on average three quarters of the overall sample (from two-third to 90%). Participants were largely in their early adulthood (early 20s to 30s). Few studies provided details on other socio-demographic characteristics, beyond age and gender, of the participants, an exception being ethnicity for studies from the USA and Australia. One USA trial on university students reported that half of its participants were Asian (50%) outweighting those who were White/Caucasian (43%), with only 3% of African American/Black participants [48]. The other studies from the USA showed instead a majority of White/Caucasian over Asian and Black/African American participants: the percentages were 59%, 18%, and 13% respectively in another study on students [42]; 82%, 4%,and 10% in a furtherUSA App trial [5], and 65%, 23%, 7% in a web-based stress management program [40]. In Australia a trial reported that half of its participants were Caucasian (53%), 15% Asian, 3% African and only 0.8% Aboriginal/Torres Strait Islander, and a further 17% preferred not to provide ethnicity details [44]. Lastly, in an Australian study of a university students virtual clinic 65% of participants were Caucasian, 28% Asian, 1% African, and 1% Aboriginal, Torres Strait and Pacific Islander [49].

Figure 1: PRISMA flowchart

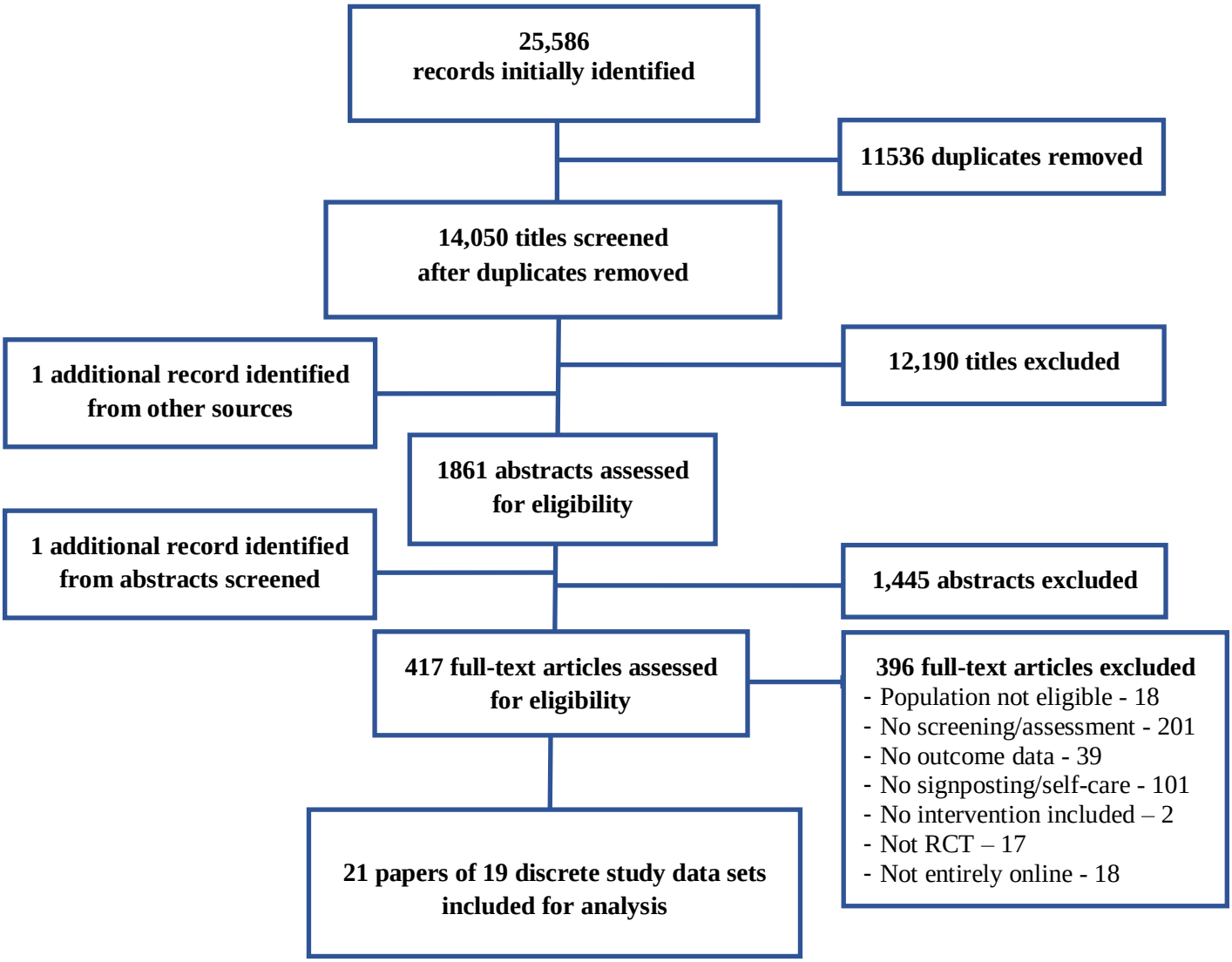


Table 1: Summary of included studies

Study Country	Target CMD	Intervention approach (n) Gender distribution %-F/M/Other & age	Comparison(s) (n) Gender distribution %-F/M/Other & age	Outcomes with validated measures
Batterham, 2016 [39] Australia	Depression, anxiety	Online assessment with tailored feedback and health-information on depression or anxiety respectively (n=1342, US, US)	No tailored feedback, just generic advice (n=1431, US, US)	AHSQ, PHQ-9, GHSQ, AQoL-4D
Batterham, 2017 [38] Australia	Depression, anxiety, substance use, suicidal ideation	FitMindKit – tailored feedback with 10 core and 8 elective behaviour therapy modules based on symptom profile (n=66, 86% F, 14% M, US)	Static FitMindKit - with no tailored feedback (n=62); attention-control - an online HealthWatch programme (n=62,86% F, 14% M, US)	PHQ-9, GAD-7, PADIS, SOPHS, AUDIT, DUDIT, SIDAS
Billings, 2008 [40] USA	Stress, depression, anxiety, substance abuse	Stress & Mood Management - online multimedia health promotion CBT programme (n=154, 71% F, 29% M, US)	Waitlist control (n=155, 71% F, 29% M, US)	SDS, PNAS, CES-D, BAI, ATSPPPH-SF, SRSQ, WLQ
Chiauzzi, 2008 [42] USA	Stress, anxiety, health behaviours	MyStudentBody – Stress - tailored motivational feedback upon completion of five online questionnaires (n=80, 48%M, 52% F, US)	Control website with no tailoring (n=80) No Treatment Control (n=80, 48%M, 52% F, US)	PSS-10, HPLP-II, CAS
Eimontas, 2018 [51] Lithuania	Adjustment disorder	BADI (Brief Adjustment Disorder Intervention), an internet-based unguided self-help psychological intervention for ICD-11 Adjustment disorder (n=516, 82% F, 18% M, mean age = 35)	BADI-T group - BADI intervention augmented with online therapist support (n=561, 82% F, 18% M, mean age = 35)	ADNM-8, WHO-5
Eimontas, 2018a [50] Lithuania	Adjustment disorder	BADI (Brief Adjustment Disorder Intervention), an internet-based unguided self-help psychological intervention for ICD-11 Adjustment disorder (n=156, 82% F, 18% M, mean age =35)	Waitlist control (n=128, 82% F, 18% M, mean age = 35)	ADNM-8, WHO-5
Farrer, 2019 [49] Australia	Depression, anxiety	UVC (Uni Virtual Clinic), a multi-component, transdiagnostic online mental health program designed for university students (n=102, 78% F, 17% M, 5% other, mean age = 22)	Waitlist control (n=98, 78% F, 17% M, 5% other, mean age = 22)	PHQ-9, GAD-7, SOPHS, K10, EURO-HIS 8, GSE-10, CSEI, ATSPPH-SF
Fulmer, 2018 [48] USA	Depression, anxiety	TESS, two versions of an integrative psychological AI chatbox fully automated intervention for 2 weeks with daily check-ins (n=24) or 4 weeks with biweekly check-ins (n=26, 70% F, 29% M, 1% other, mean age = 23)	Attention-control - link to an e-book on depression (n=24) (70% F, 29%M, 1% other, mean age = 23)	PHQ-9, GAD-7, PANAS
Haga, 2019 [53] Norway	Perinatal depressive symptoms	Mamma Mia, fully automated preventive intervention for perinatal depressive symptoms and usual care (n=678, 100% F, mean age = 31)	Treatment as usual (up to 14 consultations at well-baby clinic) (n=664, 100% F, mean age = 31)	EPDS

Study Country	Target CMD	Intervention approach (n) Gender distribution %-F/M/Other & age	Comparison(s) (n) Gender distribution %-F/M/Other & age	Outcomes with validated measures
Ketalaar 2013* [41] The Netherlands	Stress, functioning and fatigue	Screening and personalised feedback followed by tailored offer of self-help e-mental health intervention based on symptoms (n=178, 83% F, 17% M, mean age = 37)	Waitlist Control (n=188, 77% F, 23% M, mean age = 42)	NWFQ, 4DSQ, QEEW, WAI, IES (Dutch)
Ludtke, 2018 [47] Germany	Depression	Be Good to Yourself CBT-based mobile self-help app (n=44, 82% F, 18% M, mean age = 41)	Waitlist control (n=44, 75% F, 25% M, mean age = 45)	PHQ-9, Rosenberg Self-Esteem Scale. WHOQOL-BREF, URICA, CSQ-8
Mak, 2018* [43] Hong Kong	Psychological distress	Living With Heart App providing a Mindfulness-Based Program (n=703) or a Self-Compassion Program (n=705) (73% F, 27% M, mean age = 34)	Online Cognitive Behavioural Psychoeducation Program (n=753, 73%, 27% M, mean age = 34)	WHO-5, K6, MAAS, Self Compassion Scale
Moberg, 2019 [5] USA	Stress, anxiety, depression	Pacifica, fully automated app for the self-management of stress, anxiety and depression app (n=253, 74% F, 23% M, 3% Other, mean age = 30)	Waitlist (n=247, 75% F, 23% M, 2% Other, mean age = 30)	DASS-21, PHQ-8, GAD-7, GSE-10
Proudfoot, 2013 [37]	Depression, Anxiety, Stress	myCompass - fully automated, non-therapist supported psychological treatment tailored to the user (n=472, 70% F, 30% M, mean age = 39)	Waitlist (n=230, 70% F, 30% M, mean age = 38) Attention-control (n=248, 70% F, 30% M, mean age = 40)	DASS-21, WSAS
Querstret, 2018 [54]	Stress, depression, anxiety	Be Mindful Online – an Online mindfulness-based cognitive therapy course (n=60, 81% F, 19% M, mean age = 40)	Waitlist (n=58, 81% F, 19% M, mean age = 42)	Symptom severity
Solomon, 2015 [52]	Depression, Anxiety, Stress	MyCompass – same as Proudfoot et al., 2013. Sample size not applicable due to modelling and simulation used (US)	Anti-depressant medication, or CBT (US)	Quality Adjusted Life Years
Stallman, 2019 [46]	Psychological distress	My Coping Plan app, offering automated support to build an individualized coping plan (n=28, 91% F, 9% M, mean age = 29)	Waitlist (n=28, 91% F, 9% M, mean age = 29)	K10, CI, WHO-5
Viskovich, 2018 [44]	Psychological distress	YOLO Program, a web-based multimedia Acceptance and Commitment Therapy with 4 modules, offered in 3 derivatives: 1. complete one module per week but fully flexible (n=40, 75% F, 25% M, mean age = 27)	2. to complete YOLO program in 4 weeks (n=43, 75% F, 25% M, mean age = 27); 3. to access a YOLO module three days after completion of prior module (n=47, 75% F, 25% M, mean age = 27)	DASS-21, MHC-SF, SCS-SF, SWLS, DDQR, AAQ-II, CFQ, PVQII education values subscale, ELS, MAAS, SUS
Viskovich, 2019 [45]	Depression, anxiety, stress	YOLO Program – a multimedia Acceptance and Commitment Therapy with 4 modules, as above (n=596, 68% F, 32% M,	Waitlist (n=566, 68% F, 32% M, mean age = 27)	DASS-21, MHC-SF, SCS-SF, SWLS, AAQ-II, CFQ, PVQII

Study Country	Target CMD	Intervention approach (n) Gender distribution %-F/M/Other & age	Comparison(s) (n) Gender distribution %-F/M/Other & age	Outcomes with validated measures
		mean age = 27)		education values subscale, ELS, MAAS, SUS

CMD – common mental disorder or symptoms; (n) – sample size; gender distribution – Percentage of female, male, or other/unspecified participants; RCT - Randomised controlled trial; US – un-specified; AHSQ – Actual Help Seeking Questionnaire; PHQ 9 - Patient Health Questionnaire-9 items; GHSQ - General Help Seeking Questionnaire (GHSQ); AQoL - Assessment of Quality of Life; GAD-7 – Generalised Anxiety Disorder-7; PADIS – Panic Disorder Screener; SOPHS -Social Phobia Screener; AUDIT – Alcohol Use Disorders Identification Test; DUDIT – Drug Use Disorders Identification Test; SIDAS – Suicidal Ideation Attribution Scale; SDS -Symptoms of Distress scale; PANAS – Positive and Negative Affect Schedule; CES-D(R) – Centre for Epidemiologic Studies Depression Scale (Revised); BAI – Beck Anxiety Inventory (BAI); SRSQ – Stress Relief Strategies Questionnaire; ATSPPPH-SF – Attitudes towards seeking professional psychological help scale short form; WLQ – Work Limitations Questionnaire; PSS – Perceived Stress Scale; HPLP-II – Health-Promoting Lifestyle Profile II; CAS – College Adjustment Scales; ADNM-8 – Brief Adjustment Disorder New Model Scale; WHO-5 – World Health Organization Well-being Index; K10 – Kessler 10 items Psychological Distress Scale; EURO-HIS 8 – shortened version of the World Health Organization Quality of Life Instrument-Abbreviated Version; GSE-10 – General Self Efficacy Scale; CSEI – College Self-Efficacy Inventory; EPDS – Edinburgh Postnatal Depression Scale; NWFQ – Nurses Workforce Functioning Questionnaire; 4DSQ – Four Dimensional Symptoms Questionnaire; QEEW – Questionnaire on the Experience and Evaluation of Work; WAI – Work Ability Index; WHOQOL-BREF – World Health Organization Quality of Life Instrument-Abbreviated Version; URICA – University of Rhode Island Change Assessment ; CSQ-8 – Client Satisfaction Questionnaire; K6 Kessler 6 items Psychological Distress Scale; MAAS – Mindful Attention and Awareness Scale; DASS-21 – Depression Anxiety and Stress Scales-21; PHQ-8 – Patient Health Questionnaire-8 items; WSAS – Work and Social Adjustment Scale; FFMQ-SF – Five Facets Mindfulness Questionnaire Short Form; CI – Coping Index; MHC-SF – Mental Health Continuum Short Form; SCS-SF – Self-Compassion Scale Short Form; SWLS – Satisfaction with Life Scale; DDQR – Daily Drinking Questionnaire Revised; AAQ-II – Acceptance and Action Questionnaire II; CFQ – Cognitive Fusion Questionnaire; PVQII – Personal Value Questionnaire II; ELS – Engaged Living Scale; SUS – System Usability Scale. *denotes the major publication for the same study sample and data.

Intervention designs and features

Sixteen digital interventions were reported by the 19 included studies: one brief adjustment disorder intervention was trialled in two RCTs in Lithuania [50,51], a web-based acceptance and commitment therapy intervention was tested in two studies in Australia [44,45], and again in Australia a web-based intervention targeting mild to moderate depression was reported in both an effectiveness trial [37] and a health economic study [52].

In terms of intervention approaches, most offered web-based screening using various validated CMD measures followed by automatically generated (individualised) feedback including classifying the users' CMD symptom levels, from no risk to high risk. All interventions we included offered signposting to relevant services or resources including self-management strategies, such as mood or progress monitoring, relaxation strategies including meditation, mindfulness, and self-compassion, goal setting, journaling, and activating exercises. Some interventions further used the screening results to assign individuals into a relevant online mental health treatment pathway, using artificial intelligence algorithms [39,48].

The mode of delivery and design features of the interventions are summarised in Table 2. Most were delivered through a web-based portal allowing users to access it through any device with a web browser [37-39,44,49,50,53,54]. Some were specifically developed and trialled as mobile Apps [5,43,46,47]. There was one fully artificial intelligence (AI) chatbox [48]. All included trials tested digital self-care interventions, often incorporating psychoeducation [39,40,53] and various other psychological intervention modalities. Most commonly employed intervention strategies included mindfulness [5,43,47,50,54], compassion, CBT [5,47,50], acceptance and commitment therapy [44,45], motivational interviewing [48], and positive psychology mobilising the individual's strengths [46,48]. Five interventions included an interactive forum where users can exchange discussions with one another [5,38,39,43,46].

Limited details of the digital intervention designs and ICT features were reported. Explicit theoretical basis underpinning the design and delivery integrating algorithm and web-based behavioural change techniques was generally lacking. Across studies, only a few online behavioural change techniques were explicitly adopted by the interventions and these included: provision of feedback on performance [39,51]; goal setting [46]; prompts for self-monitoring of behaviour and progress [37,43,49]. Intervention duration and intensity varied widely across studies, with most interventions were for 4 weeks [43,44,46], a few lasting 3 months [38,39,41], and the longest lasting 11 months [53]. Most interventions did not stipulate the minimum usage requirement and recommended the users to use the intervention as preferred [38]. Some interventions had a set number of modules to be undertaken over a set time frame. However, these did not necessarily translate into minimum usage requirement, intervention duration, or intensity [37,38,53].

INSERT TABLE 2 HERE

Table 2: Mode of delivery used by included interventions

Study	Delivery platform				Social network	Treatment recommendations				Cost		
	App	PC	Both	Other		Self-care	Informal support	Formal service	Other	Free	Paid	Not stated
[39]			X	X	X	X	X		X			X
[38]		X			X	X	X		X	X		
[40]		X				X		X	X	X		
[42]		X				X			X			X
[50]			X			X				X		
[49]			X			X			X			X
[48]				X		X			X	X		
[53]			X			X				X		
[41]		X				X			X			X
[43]			X		X	X			X	X		
[47]	X					X			X			X
[5]	X				X	X	X					X
[37]			X			X			X	X		
[54]		X				X				X		
[46]	X				X	X	X	X		X		
[45]		X				X				X		

SMS = short message service; PC = personal computer; *data from Eimontas 2018, Proudfoot, 2013, Viskovich 2019 used for intervention description

Study designs and outcome measures used

Included studies, all bar one, used an individual-level randomised controlled trial (RCT) design. Only one study used a cluster RCT design at a ward-level where nurses and allied health professionals were allocated according to their work base within a hospital in the Netherlands [41]. All studies examined digital intervention effectiveness, with one including a health economic modelling study comparing cost-effectiveness of the digital intervention with anti-depressant medication (as treatment as usual) or CBT for mild to moderate depression in Australia [37,52]. Comparison conditions used in the included RCTs were grouped into (1) inactive controls and (2) active controls. The former includes usual care delivered using conventional medium [53] or wait list controls [5,37,40,41,45-47,49,50,54]. The latter comprises attention-control (e.g. static websites with information or an ebook [37-39,48]). One trial included three arms, comparing the digital intervention with both an attention control and a wait list control [37], we used such data in separate analyses. Two 3-arm trials compared three different formats of the same digital intervention head to head with no other comparison groups comprising non-digital elements [43,44], no usable comparison data could be extracted for analyses. Data from one trial which compared an entirely online self-care intervention for university students with a version of the intervention augmented with therapist input also delivered through its online platform was not usable in the analysis [51].

All trials investigating digital intervention effectiveness used outcome measures of mental illness symptoms, including stress, anxiety, depression, and general distress. Three studies measured wellbeing [45,46,50] and only one measured quality of life at post-intervention and 3-month follow-up respectively [39,47]. Help-seeking attitude [40] and service use [39] were each measured by one study at each time point. Work or general functioning was assessed by three studies [37,40,41]. Two studies reported coping as an outcome but one each focused on overall coping [46] or negative coping [40] respectively. Satisfaction with intervention, if assessed, focused only on the intervention group participants and the measures or tools used were often unvalidated or devised by the study teams on an ad hoc basis [44,45,50].

In terms of intermediate outcomes, one study measured knowledge of common mental disorder symptoms, prevention and treatment [40]. Use of health promoting behaviours was covered in only one study [42], though many reported therapy-specific measures to assess engagement with therapy approaches (e.g. compassion, cognitive flexibility, willingness to change). Although behaviour change techniques, most often goal setting, prompts for self-monitoring or action planning, were reported to form part of the intervention design [37,43,46], no data on uptake of recommendations or behavioural activation outcomes were available, if measured.

Overall study quality

Our evaluation of the study quality and the comparison of the global ICROMS score of each study against the ICROMS minimal score requirement is presented in Table 3. The ICROMS global quality scores range from 14 to 29; six (33%) trials were rated below the minimum score of 22. Although the RCTs were published relatively recently, some did not fully adhere to the CONSORT or CONSORT-eHealth checklist [40]. Many of the RCTs did not publish their protocols or prospectively register the study on trial databases to provide detail on the intervention design and required minimum intervention exposure (i.e. per protocol use) or state a priori primary outcomes [42,45,46]. While randomisation and allocation using a computerised or online system were often cited, details on the randomisation sequence generation and allocation concealment were often minimal if at all reported [5,43,44,47,50,51]. Given waitlist control or usual care was most commonly used as the comparator, it was not feasible to blind the participants, though there were few exceptions [49,54]. While outcome data collection using online questionnaires with the participants directly reduced bias in assessment, limited considerations were conveyed to establish whether the researchers or trial statisticians conducting the data analysis were blind to group allocation [5,43,44,47,50,51]. Nonetheless, the most significant quality issue identified here concerns retention and completion rates in digital health intervention trials. Intention to treat (ITT) analysis were not always used and there was a lack of available data for non-completers [40,41,44,45,50,51]; these quality issues might bias the study results and overall evidence. Another area of potential bias lies in reporting or ethical considerations as not all studies reported their funding sources and conflicts of interests. Further, a few of the trialists reported a digital intervention produced by commercial enterprises in which they had a financial interest [5,42,48].

We rated the quality of the health economic study [52] as satisfactory, according to CHEERS [35]. The paper addressed 18 out of 24 (67%) CHEERS quality criteria, including clear reporting of method, analysis, results and discussions. Four checklist criteria were deemed irrelevant in this study (e.g. not a single study-based economic evaluation, and hence no such study parameters). Quality criteria that were not addressed concerned discount rate(s) used for costs and outcomes (if any) and justification of the choice of model used.

INSERT TABLE 3 HERE

Table 3: Quality assessment of included studies using ICROMS (needs to update)

Study name (first author only)	Study design	Aims & justifications	Sequence generation & allocation concealment	Outcome measures & blinding	Follow up	Other study aspects	Analytical rigor	Other considerations	Global quality score
Batterham, 2017 [38]	RCT	2	3	3	5	2	2	11	28
Batterham, 2016 [39]	RCT	2	4	4	6	2	2	8	28
Billings. 2008 [40]	RCT	0	2	1	3	2	1	5	14
Chiauzzi, 2008 [42]	RCT	2	4	2	5	2	2	7	24
Eimontas, 2018 [50]	RCT	1	1	2	5	2	1	7	19
Eimontas, 2018a [51]	RCT	2	1	4	5	2	1	8	23
Farrer, 2019 [49]	RCT	2	4	4	5	2	2	9	28
Fulmer, 2018 [48]	RCT	2	2	4	4	2	1	4	19
Haga, 2019 [53]	RCT	2	3	4	6	2	2	9	28
Ketelaar, 2013 [41]	cRCT	2	4	2	6	2	0	6	22
Ludtke, 2018 [47]	RCT	1	2	4	6	2	2	7	24
Mak, 2018 [43]	RCT	2	2	4	6	2	2	8	26
Moberg, 2019 [5]	RCT	2	1	4	4	2	1	5	19
Proudfoot, 2013 [37]	RCT	2	3	2	5	2	2	8	24
Querstret, 2018 [54]	RCT	2	4	6	6	2	2	7	29
Stallman, 2019 [46]	RCT	2	4	4	5	2	1	7	25
Viskovich, 2018 [44]	RCT	1	1	4	4	1	1	6	18
Viskovich, 2019 [45]	RCT	2	2	3	4	1	1	6	19

ICROMS minimal score requirement for (Cluster) randomised controlled trial = 22;
Comparison against minimal score requirement: below requirement or met or above requirement;
RCT – randomised controlled trial; cRCT – cluster randomised controlled trial

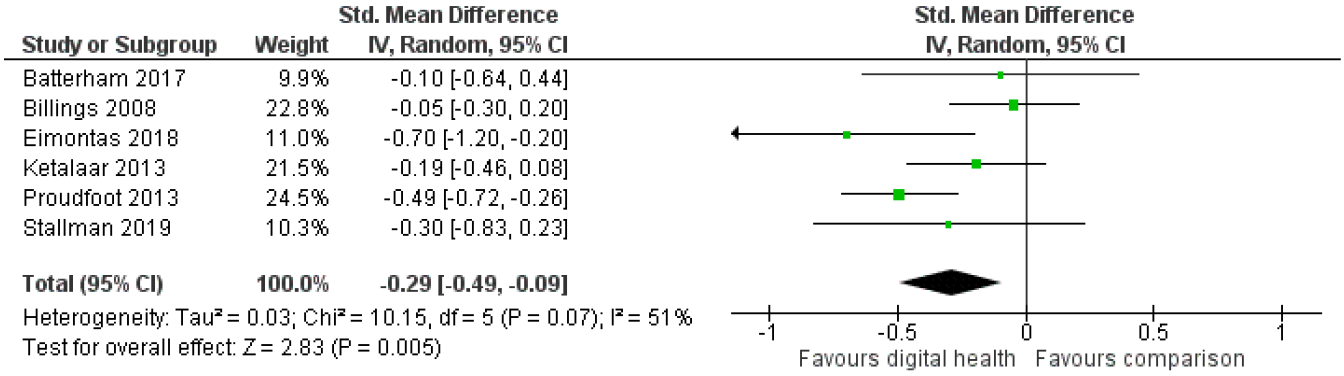
Effectiveness

Six RCTs [37,38,40,41,46,50] reported outcomes using measures of mental illness symptoms (as a composite measure encompassing depression, anxiety, and distress or psychological distress) at the end of the intervention use. These studies examined the effectiveness of tailored digital interventions comparing with waitlist control [37,40,41,46,50] or attention-control [38]. The meta-analysis including these six studies showed an overall significant small effect of digital intervention compared to controls in reducing mental illness symptoms (6 RCTs, n = 992, SMD -0.29, 95% CI -0.49 to -0.09, I^2 = 51%, random effects, GRADE quality of evidence = moderate). Comparing digital interventions with waitlist controls only using data from 5 trials led to a similar result favouring digital interventions (5 RCTs, n = 939, SMD -0.31, 95% CI -0.54 to -0.09, I^2 = 59%, random effects, GRADE quality of evidence = low). There were only two trials providing data for comparing digital interventions with attention controls [37,38]. Meta-analysis including these data still yielded a significant result favouring digital intervention (2 RCTs, n = 374, SMD -0.31, 95% CI -0.52 to -0.10, I^2 = 0%, fixed effect, GRADE quality of evidence = very low). See Figure 2 for meta-analyses on the outcome of mental illness symptoms.

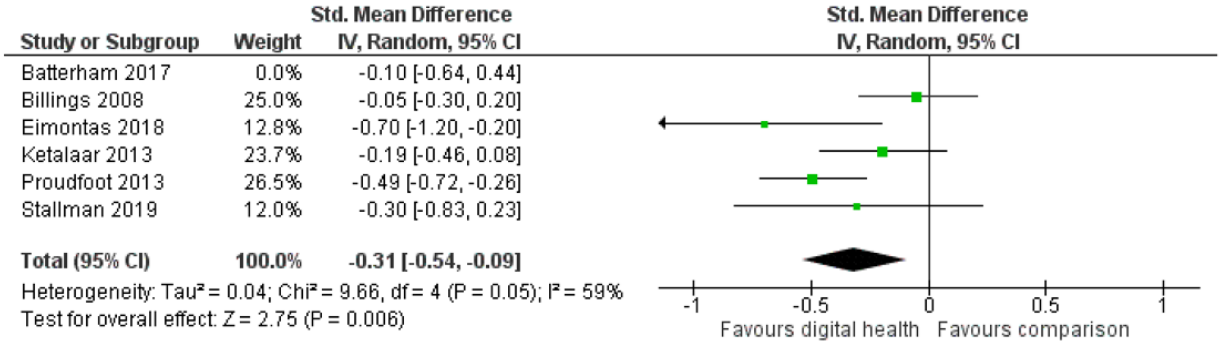
INSERT FIGURE 2 HERE

Figure 2: Meta-analysis on outcome of mental illness symptoms

2(a) Comparison of digital interventions with any comparators using all available data



2(b) Comparison of digital interventions with waitlist controls only

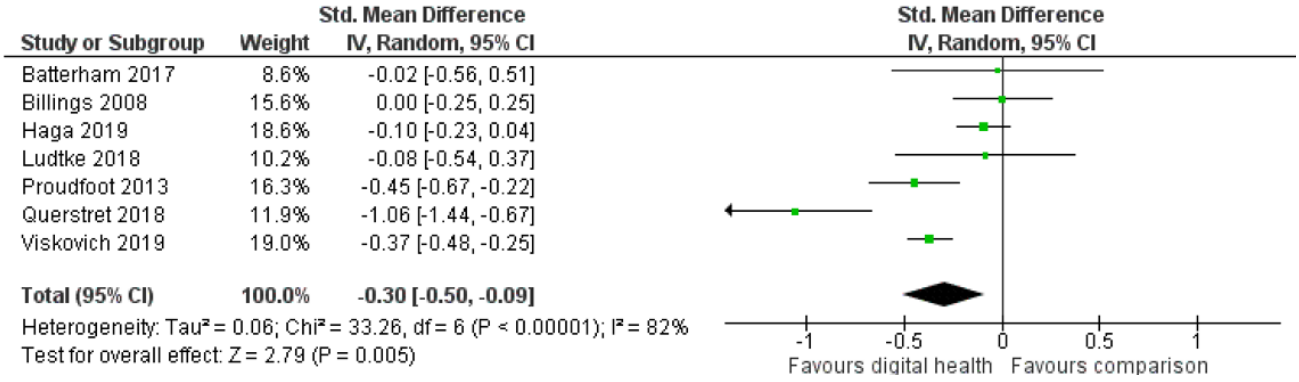


Seven studies measured participants' depressive symptoms [37,38,40] comparing digital interventions with inactive controls [37,40,45,47,53,54] or attention controls [38]. Digital interventions showed a

small but significant positive effect over any comparisons (7 RCT, n = 2824, SMD -0.30, 95% CI -0.50 to -0.09, I^2 = 82%, random effects, GRADE quality of evidence = low). Heterogeneity of this meta-analysis was high: three were European studies including one focusing on post-natal depression in new mothers through a year-long intervention across the perinatal period [53]; three were conducted in Australia comprising nearly half of the total participants in this analysis; and the remainder in USA. See Figure 3 for the meta-analysis on depressive symptoms.

INSERT FIGURE 3 HERE

Figure 3: Meta-analysis on outcome of depressive symptoms



Meta-analysis on participants' anxiety symptoms from five studies produced similarly positive results favouring digital interventions to inactive or attention controls (5 RCT, n = 1893, SMD -0.37, 95% CI -0.65 to -0.08, I^2 = 84%, random effects, GRADE quality of evidence = low). The high heterogeneity is likely due to diverse intervention, population, and methodological factors [37,38,40,45,54]. See Figure 4 for meta-analysis on anxiety symptoms. Three studies reported stress outcomes but only data from two of these were usable in the meta-analysis [41,45,54]. The analysis showed a significant positive effect over waitlist controls (2 RCTs, n = 1280, SMD -0.43, 95% CI -0.54 to -0.32, I^2 = 94%, fixed effect, GRADE quality of evidence = very low). Of note, heterogeneity of these two studies was high: one trialled an online mindfulness CBT for UK workers [54]; the other investigated a web-based acceptance and commitment therapy for university students in Australia [45]. See Figure 5 for meta-analysis on stress outcome.

INSERT FIGURE 4 AND FIGURE 5 HERE

Figure 4: Meta-analysis on outcome of anxiety symptoms

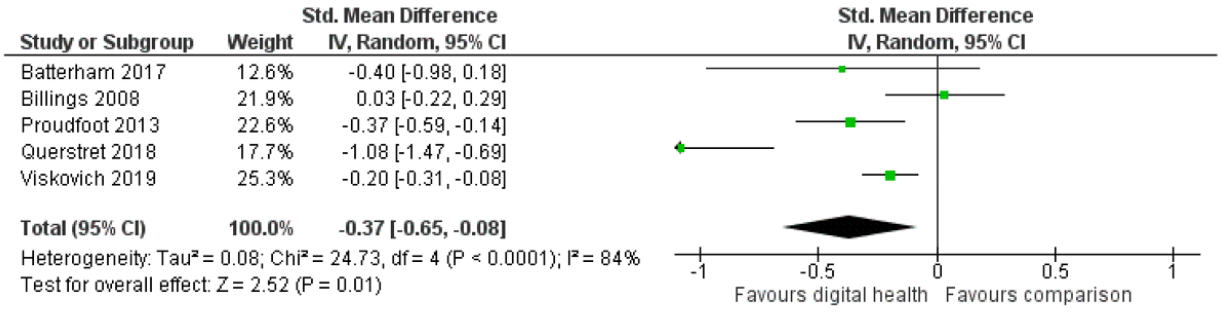
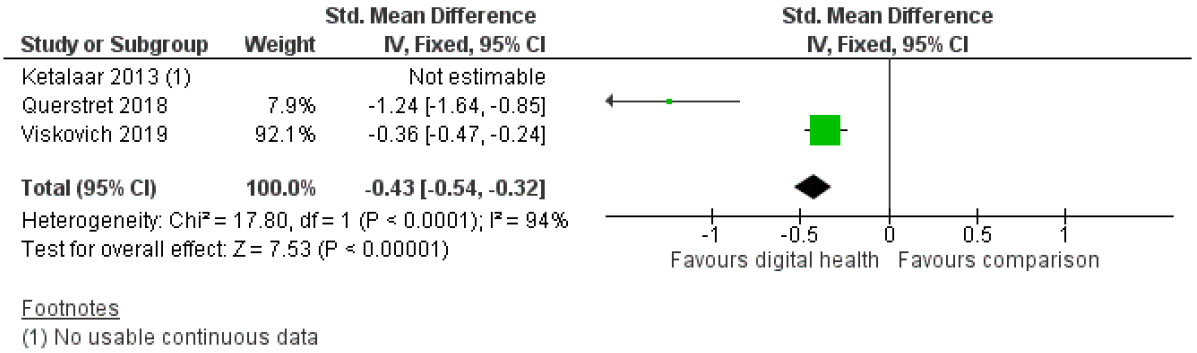


Figure 5: Meta-analysis on outcome of stress symptoms

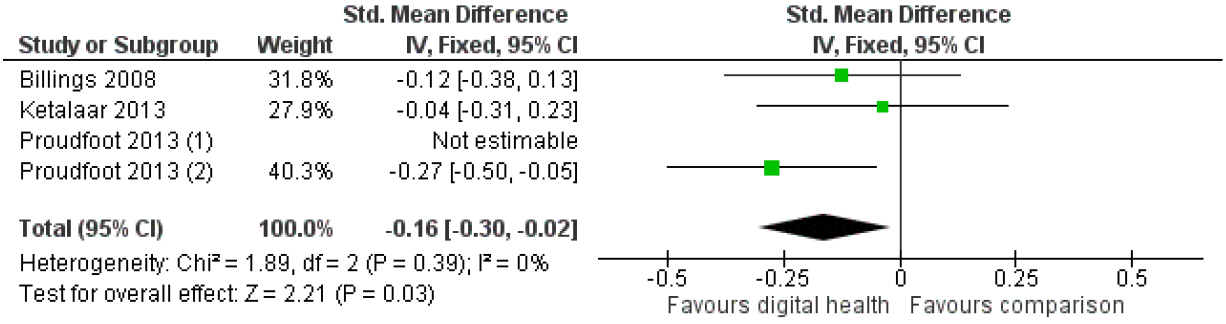


Footnotes
(1) No usable continuous data

In terms of work and social functioning outcomes, three studies compared digital interventions with inactive controls [37,40,41] while one study included a second control group using attention control [37]. Results comparing digital interventions with any comparators were equivocal across groups (3 RCTs, n = 792, SMD -0.13, 95% CI -0.27 to 0.01, I^2 = 0%, fixed effect, GRADE quality of evidence = low). However, when comparing digital interventions with inactive controls only, digital interventions showed a significant albeit small effect over waitlist (3 RCTs, n = 795, SMD -0.16, 95% CI -0.30 to -0.02, I^2 = 0%, fixed effect, GRADE quality of evidence = low). See Figure 6 for meta-analysis on work and social functioning outcome.

INSERT FIGURE 6 HERE

Figure 6: Meta-analysis on outcome of work and social functioning comparing digital interventions with inactive controls

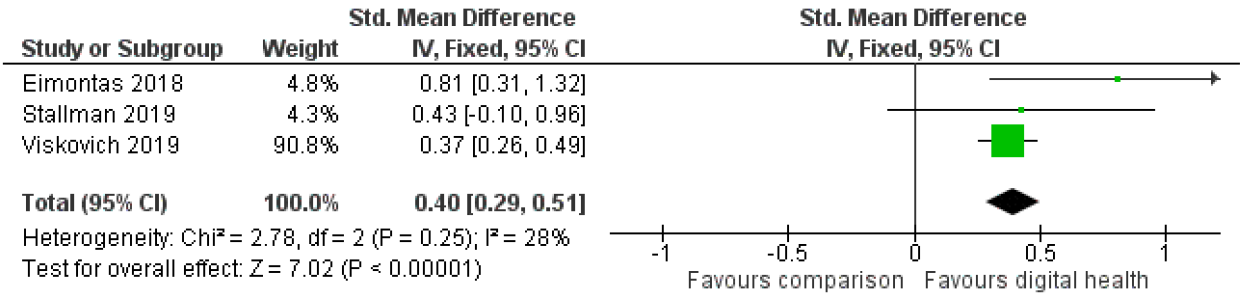


Footnotes
(1) Digital intervention compared with attention control
(2) Digital intervention compared with Waitlist

Three studies examined the effectiveness of digital interventions on wellbeing [45,46,50]; digital interventions delivered as web-based cognitive behavioural therapy or acceptance and commitment therapy or mobile App showed a significant positive effect over waitlist control (3 RCTs, n = 1307, SMD 0.40, 95% CI 0.29 to 0.51, I^2 = 28%, fixed effect, GRADE quality of evidence = low). It is worth noting that this result was weighted heavily by one study conducted in Australia on over 1100 university students [45]. See Figure 7 for meta-analysis on the wellbeing outcome. Only one study measured participants' quality of life as an outcome when comparing digital intervention with waitlist control [47].

INSERT FIGURE 7 HERE

Figure 7: Meta-analysis on outcome of wellbeing comparing digital interventions with inactive controls



Follow up outcome data

Follow up data (beyond 3-month) were limited. Four studies [37-39,41] provided data with one study delivered two active interventions focusing on depression or anxiety management respectively, each comparing with an attention control [39]. Meta-analyses using the available 3-month follow up data revealed no significant differences on mental health and work and social functioning outcomes, between digital interventions and controls, active or inactive. See Table 4 for summary of meta-analysis results, using fixed effect model.

INSERT TABLE 4 HERE

Table 4: Summary of meta-analyses on 3-month follow up outcome measures

Outcome measures	Studies	Sample (N (n/n))*	SMD	95% CI	I^2 (%)
Mental illness symptoms	3	521 (194/327)	-0.12	-0.30 to 0.05	1
Depression	3	1209 (509/700)	-0.04	-0.15 to 0.08	0
Anxiety	3	1044 (431/613)	-0.20	-0.87 to 0.47	0
Work and social functioning	2	476 (171/305)	-0.13	-0.32 to 0.06	0

*Total number of participants included in the analysis (number of participants in digital interventions/number of participants in comparator groups)

Health economic outcomes

No RCTs included a cost-effectiveness evaluation. One Australian RCT on a digital intervention, myCompass, designed to treat mild to moderate depression in the general population [37], was used as the basis of a decision analytic model [52]. The model employed a cost-utility framework to compare the costs of myCompass with each of treatment as usual (antidepressant treatment) and face-to-face cognitive behavioural therapy. The results of the model suggested that the myCompass intervention provided the highest net monetary benefit and the authors concluded that digital interventions could provide a cost-effective route to treatment as part of a stepped care model [52].

Intermediate or process outcomes

There were no usable data available from RCTs on any of our pre-specified intermediate or process outcomes (e.g. uptake of self-care or informal support, health behaviour change), precluding analysis on such outcomes in its own right or meta-regression on any association between intermediate and health outcomes. Some studies reported therapy-specific mediating measures, such as willingness to change measure in a CBT-based mobile App [47] or self-compassion or five-facet mindfulness questionnaires in third-wave web-based cognitive behavioural therapies [45,54]. These fell short of health behaviour change outcomes and were therapy specific; we therefore considered inappropriate to compare such outcomes across studies.

Perceived acceptability of interventions

If reported, study findings on satisfaction were collated via self-devised measures or unvalidated survey post-intervention use, lacking corroboration from validated outcome data and comparison with the control groups or any other interventions. No analysis on this outcome was feasible.

Discussion

This comprehensive review included 18 RCTs and one health economic study on 16 interventions to examine the effectiveness of digital interventions which provided both initial assessment and treatment emphasising self-care, using a web-based medium entirely. Fourteen of the included trials were only published in the preceding five years, suggesting that despite the popularity of digital mental health interventions, rigorous research undertaken in this field is still emerging.

Our review identified some evidence to support the effectiveness of digital interventions in promoting wellbeing among university students [45,46,50] and in reducing symptoms of common mental disorder, depression, anxiety, stress and promoting social and work functioning. These positive results on CMD symptoms came from studies on non-clinical young adult samples (aged between early 20s to 30s) among the general population with mild baseline symptoms [37,38,41,45,46,50,54]. It is highly plausible that the study samples recruited included a high proportion of people who had low intensity of CMD symptoms which might not meet threshold of clinical caseness or needs for conventional mental health interventions delivered by clinicians (e.g. CBT or counselling). Uptake of interventions showed a majority of participants with a White/Caucasian background, with Asian being the second most frequent group reported and Black/African American usually third. Unfortunately, information about race/ethnicity of participants was available for only six studies [5,40, 42, 48,49,44], limiting the analysis on plausible cultural determinants of digital health performance. Similar to conventional trials on psychological interventions delivered face to face, two-third of the study participants were female [16-18]. Furthermore, some of the included studies were designed primarily as a mental health promotion or preventative intervention, for example for college students and new mothers [46,49,53]. Despite this aim, there was in general a lack of focus on positive psychological outcomes such as wellbeing or quality of life. Further there may be a ceiling effect with respect to the population means at baseline or study entry, leaving little room for improvement in outcomes.

Most of the interventions examined were designed to be accessed and used autonomously by the users [5,37,43,48,50]. Commonly, users were advised to use the intervention flexibly suiting their own

preference as much or as often as necessary or desired though encouraged to make full use of the intervention elements (e.g. forum, exercises, monitoring) and content. A small proportion of interventions, however, guided their users through "core" content through a specific sequence (e.g. to complete 4 modules in a pre-determined order [38,47]) or over a specific timeframe (e.g. one module a week or at a certain time point, such as 3 week after giving birth [53]). While online recruitment across studies was largely successful, retention and completion rates reported across trials are concerning. With a couple of trials achieving retention rate ≥ 80% (e.g. [46,48]) as exceptions, attrition rates range from 27% in an Australian trial of a digital depression and anxiety intervention [37], to 78% in a mobile App trial [5,43] and 87% in a web-based intervention [50], post-intervention. Attrition at short-term follow-up is equally high (e.g. 83% at 3-month follow up [39]) while most of the included studies do not report follow up beyond the immediate post intervention time point. Further, the low usage or adherence rate across trials was often cited to account partly for the equivocal results across groups [5,43,50], raising the possibility that no effect was due to low or no minimally sufficient treatment "dosage". The low usage of digital interventions also prompts doubts over the value of the automatic reminders (as emails or SMS/mobile App prompts) integral to digital intervention design and delivery in the entirely self-guided treatment. Our review shows that even though many interventions sent automatic daily or weekly reminders or prompts to the participants directly, they were not responding accordingly. These issues, although consistent with the inherent challenges of conducting digital intervention trials [57,58], remain critical to be resolved. For any digital interventions to effect meaningful changes in their users, developers need to articulate the essential intervention elements and the required intervention exposure or usage to achieve that as a crucial part of the intervention design [59]. Most importantly, it is essential for digital interventions to optimise their engagement and faciliation strategies to ensure users get the intended benefits of the intervention while enjoying their autonomy in pursuing individualised treatment. The effects of reminders and prompts functions, and indeed other communication strategies afforded by digital interventions should be carefully investigated to inform both the intervention and study designs.

In addition to the paucity of research in the growing field of digital health interventions, we note some limitations in the included studies and the data they reported. Although all interventions examined included a self-assessment component, we found no data pertaining to the effectiveness or efficiency of the assessment function independent from the overall intervention including their treatment component. No conclusions, thus, could be drawn on the impact of assessment on: the users' initial engagement with the intervention; subsequent signposting based on AI; or the users' mental health outcomes. Follow-up data were sparse, limiting analysis on outcomes beyond three-month follow up. The lack of reporting of intermediate outcomes and process evaluation data (if used) precluded any analysis to convey how digitial interventions might work to instil health outcome changes [26,27]. Although some behaviour change techniques were incorporated as intervention design (e.g. prompts for self-monitoring or goal setting), data on the target health behaviour change outcomes were generally not collected or not reported, however. While it is often argued that digital interventions carry with them the benefit to be expanded and delivered to whole populations at a relatively low cost, no data were available regarding estimating cost-effectiveness, and only one paper inlcuded economic modelling [52]. This, coupled with the unclear intervention design description limits generalisability of results and the scope of replication and wider implementation.

Limitations

We consider several limitations of this review. First, we are mindful that our results are synthesised from studies reporting different interventions targeting a wide range of populations, ranging from those promoting positive mental health to others identifying and treating mild to moderate depression. The results therefore fall short of identifying specific intervention designs (e.g. with specific ICT features) which maybe of particular effectiveness for specific populations or CMD (symptoms) groups. This approach also in part accounted for the high heterogenity observed in the meta-analsysis results. Second, given the limited amount of usable data included in the analysis especially in the follow-up timepoint, we conducted meta-analysis using the fixed-effect model on endpoint mean score whenever less than five study datasets were available. While the fixed-effect model is deemed most suitable for meta-analysis including five or fewer studies, this approach is inferior in taking baseline measurement into consideration, which is particularly important in small trials [32]. We have therefore downgraded the GRADE quality ratings accordingly [31].

Implications for research and practice

While the results from the studies reviewed appear promising, they are limited in terms of generalisability to digital interventions scaled up for use by whole populations. For example, a key implication of the results for both research and practice is the need for economic evaluation of digital mental health services for general population samples [10,60]. While the usual trial methods for cost-effectiveness evaluation would be informative, economic evaluation of the scaling up of digital interventions to whole populations is also important, as a key consideration for economic evaluation is the potential range of reach of digital services. While widespread awareness and usage of a digital service may increase its cost effectiveness, creating that awareness also has to be done in a cost efficient way. People who use non-digital health or other services can be informed of a digital service at these services, while those who only do so rarely or when in crisis but may benefit must be reached by other means. Given the interventions are online, the most obvious is to use advertising via social media in response to mental health related search terms [9,61]. Economic evaluation of scaling up requires study of the costs to create awareness of the service and modelling methods using the usage data from the service. Such models must take into account as one of their assumptions the additional use of other services, both digital and non digital, by some users. This is something likely to vary as usage increases: as more people take up a digital intervention the proportions who were previously using something else (and what that was) vs. nothing is likely to change; similarly, the intervention's cost effectiveness is likely to vary by demographic and clinical groups, and this again will change with increasing levels of use.

Outside of a research or a practice setting, the extent to which a digital service is trusted is important in addition to its usability [26,28,58]. One implication therefore is the need for research into aspects which affect this trust and how this varies within the general population, for example the need to register to use it using personal information, and the use of health service or government logos [62].

CONCLUSIONS

Digital mental health interventions to assess and signpost people experiencing symtpoms of common mental disorders appear to be acceptable to sufficient numbers of people and to have enough evidence

for effectiveness to warrant further study. We recommend future studies incorporate economic analysis; much of the work in this area appears to rest on the untested assumption that by their nature digital interventions are cost-effective. We also suggest clarification of the theoretical models for interventions. Many apply therapies such as cognitive behavioural therapy and psychoeducation to a sample with milder problems than would currently receive them, and state their aims as including both reduction in symptoms and promotion of mental health. However, positive mental health outcomes such as mental wellbeing, self-esteem, self-efficacy, coping skills, or resilience, are rarely used; this may obscure their effectiveness in the target population. Finally, process evaluation to assess implementation and mechanisms of action is needed to understand the outcomes reported, if needed in a separate publication.

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Conflict of interest
All authors declare no conflict of interest.

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